Interaction genotype-environment for dairy production in Mambi cattle from Cuba

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A total of 40 042 records of milk production accumulated up to 305 d (L305), of 15 260 Mambi de Cuba cows (3/4 Holstein ¼ Zebu), from four genetic enterprises and 177 herds were used. The study purpose was assessing the existence or not of interaction genotype-environment (IGE) for dairy production in two production levels: normal (P1, of the calving years 1981- 1990) and low (P2, of the calving years 1991-2006). A univaried animal model was applied for estimating the genetic parameters and values (GV) in both production levels and years (P3, of the calving years from 1981 to 2006). The combination herd-year-four-month period of calving, age at calving as linear and square co-variable, the animal random effects, the effect of the permanent environment and the residues were included as fixed effects. The Pearson's correlations between the GV of the 39 sires represented in both production levels were estimated. The heritability and repeatability were: 0.227 ± 0.029 and 0.473 ± 0.008, 0.059 ± 0.015 and 0.266 ± 0.014, 0.170 ± 0.020 and 0.418 ± 0.006, for the levels P1, P2 and P3, respectively. The correlation between the GV of the sires in P1 and P2 was of 0.66, so the effect of the interaction genotype-environment was proved. It is concluded that the environmental conditions should be considered for using the Mambi de Cuba sires.

Key words: *genotype-environment interaction, Mambi de Cuba cattle, dairy production, genetic parameters, genetic values*.

The genotype-environment interaction may alter the genetic, phenotypic and environmental variances and, consequently, modify the estimates of genetic and phenotypic parameters. Therefore, depending of the environment, the selection criteria can be changed and the interaction identification increases the efficiency of cattle selection (Alencar *et al*. 2005).

In previous studies of Suárez *et al*. (2009) with Siboney de Cuba breed (5/8 Holstein 3/8 Zebu) under the Cuban environmental conditions, the interaction genotype-environment on dairy production and reproduction was studied. However, there are no references on this respect for the Mambi de Cuba breed (¾ Holstein ¼ Zebu). That is why, the objective of this research was to determine the existence or not of genotype-environment interaction for dairy production under different environmental conditions (production levels) in Mambi de Cuba cattle.

Materials and Methods

The records of the milk production accumulated up to 305 d in cows of the genotype Mambi de Cuba (¾ Holstein ¼ Zebu), from four genetic enterprises (Empresa Pecuaria Genética de Matanzas, Bacuranao, Los Naranjos and Camilo Cienfuegos) in 1981-2006 were used. They are in the western region of the Republic of Cuba, an island located in the Gulf of Mexico, between 20 to 23° N and 74 to 85° W.

In Cuba, the predominating weather is tropical warm with two seasons: the rainy one, comprising between May and October and the dry one between November and April (Anon 2009). The mean annual temperature is of 24 0C, the mean relative humidity with averages close to 80 % and the rainfall surpasses 3 000 mm a year.

For a higher precision of the parameters, lactations with less than 100 d (5.35 % of the data), calving ages inferior to 24 months (0.08 % of the data) and milk production with less than 300 kg (4.22 % of the data) were eliminated. The values over and below three mean standard deviations, as well as the groups of contemporaries with less than three animals, were also excluded. The combination herd-year-four-month period of calving was considered as group of contemporaries. The lactations superior to the seventh were grouped in lactation seven.

The procedure Proc freq of the statistical software SAS (2002), version 9.0, was used for determining the frequency of daughters per sires. Those with less than 10 in both production levels (P1 and P2) were eliminated. The final sample (P3) was represented by 93 sires and had 40 042 total lactations, from 15 260 Mambi from Cuba cows of 177 herds.

The data were divided into two samples, the first with 27 573 lactations (12 011 cows), corresponding to the calving years 1981-1990 and production levels considered as normal (P1). Figure 1 shows the data distribution according to the calving year. During this period, the normal exploitation conditions with supplementation of concentrated feeds and fertilized and irrigated grasslands prevailed. The animals received, daily, commercial concentrated feed, individually, at a rate of 0.46 kg/L, after the fifth liter of milk produced.

The second sample had 12 469 lactations (7 495 cows) of the calving years 1991 - 2006, when the production levels were considered low (P2). Figure 2 shows the data distributions per calving year. This period corresponded with economic limitations in Cuba, conditions that influenced on the animlas' management and feeding. The amount of paddocks was reduced and the mean concentrate supplementation up to 1kg/animal. Since 2001, the paddocking was improved and Norgold (distillery dry grains with soluble, resulting by-product of the ethanol production process from maize) was offered at a rate of 0.46 kg/L, from the second milk liter produced. However, the conditions were not in correspondence with those of the first year of study.

The variance components, heritability (h^2), repeatability (r) and genetic values in each production level (P1, P2) and in the whole data (P3) were estimated through the software ASREML (Gilmour *et al*. 2003). The following animal univaried model was used:

$$y = Xb + Za + Wp + e$$

where:

y: vector of the milk production accumulated up to 305 d

b: vector of fixed effects having the effect of herd-year-four-month period of calving and calving age as linear and square co-variable

a: vector of random effects of the animal

p: vector of the permanent environmental effect of the cow,

X, Z and W- matrixes of design or incidence relating the fixed and random effects and those of permanent environment with the data, respectively

e: vector of random residual effects

The pedigree file was formed by 47 284 individuals. Its information on both the maternal and paternal side reached up to the grandparents. The procedure Proc Corr of the statistical software SAS (2002), version 9.0 was applied to determine the Pearson's correlation between the GV of the 93 sires represented in both production levels (P1 and P2), as well as those between each production level with all the data (P3). Figures 3 and 4 show the frequencies of the genetic values in the two production levels.

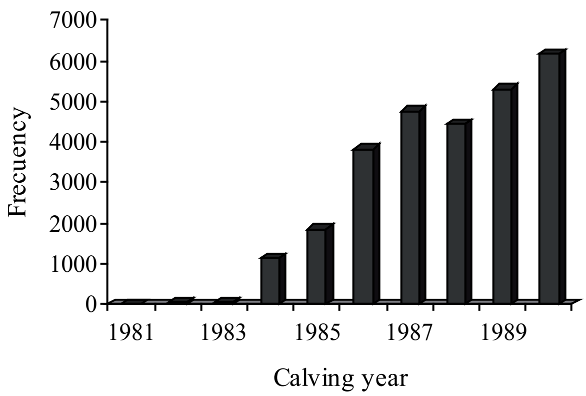

Figure 1. Distribution of the data per calving year.

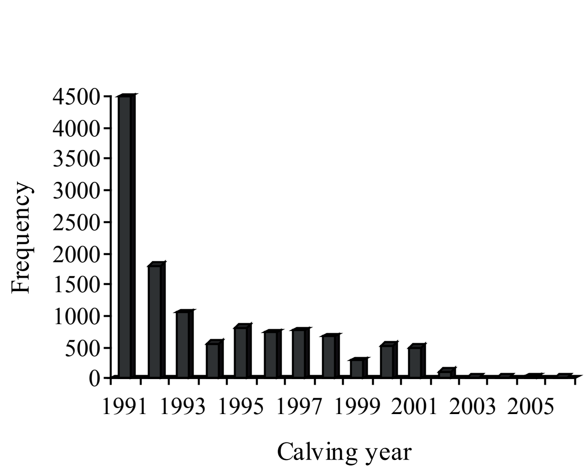

Figure 2. Distribution of the data per calving year.

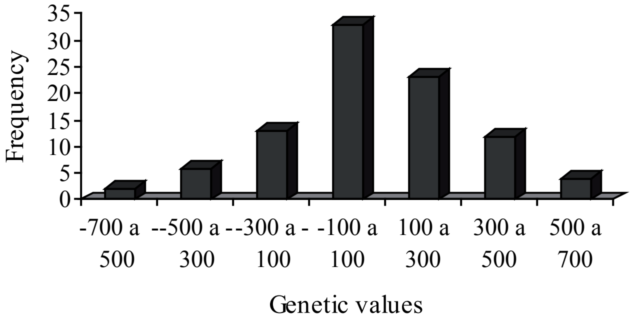

Figure 3. Frequency of the genetic values of sires in production level P1.

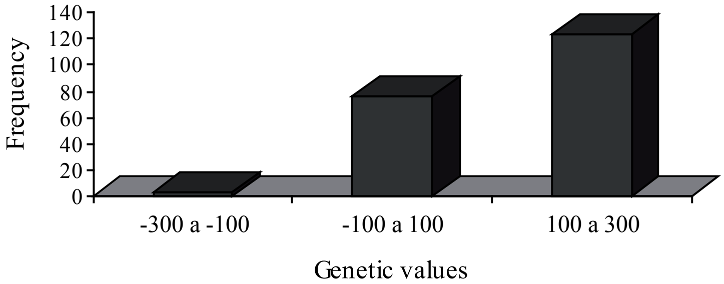

Figure 4. Frequency of the genetic values of sires in production level P2.

Results and Discussion

Table 1 presents the statistics (mean, standard deviation and variation coefficient) estimated of the variances, heritability and repeatability of milk production up to 305 d in different production levels. The averages obtained for the dairy production were superior in the normal production level (P1) compared to the lower level (P2). The difference in milk production between the levels P1 and P2 was of 1 053 kg. The averages corresponding to the whole data (P3) coincide with that reported by Ribas *et al*. (2004) for Siboney de Cuba (5/8 Holstein 3/8 Zebu).

There were differences in the estimates of the variance components, heritability and repeatability for milk production in the different production levels. According to Weigel *et al*. (1993), the differences in structure and management of the herds provoke the same in the residual variances. Cerón-Muñoz *et al*. (2001) expressed that the number of records, herds and bulls caused differences in the variants between environments.

The heritability estimate in the production level P2 diminished considerably in respect to the level P1. The low estimate obtained in level P2 was due to a higher environmental variation on the phenotype, caused by the variability increase in the exploitation conditions (management and nutrition).

Suárez *et al*. (2009), in Siboney de Cuba, obtained heritability estimates inferior to those of this study in the

Table 1. Statigraphs and estimators of the additive genetic variance (σ^2a), variance of the permanent environment (σ^2p), residual variance (σ^2e), heritability (h^2) and repeatability (r) of milk production up to 305 d in Mambi de Cuba cows, in different production level

	Production level		
	P1	P2	P3
Mean (kg)	2423.0	1370.0	2095.0
Standard deviation	662.0	520.0	632 .0
Coefficient of variation (%)	27.3	38.0	30.2
σ^2a	91216.0	12302.0	59083.0
σ^2p	98694.0	43124.0	86151.0
σ^2e	211195.0	152451.0	202191.0
$h^2 \pm$ SE	0.227 ± 0.029	0.059 ± 0.015	0.170 ± 0.020
r ± SE	0.473 ± 0.008	0.266 ± 0.014	0.418 ± 0.006

production level P1 (including the calving years 1980 - 1990), with 0.12 and similar in P2 (including the calving years from 1991 to 2000). The estimate of the data was within the range informed by Valle and Moura (1986), Guerra *et al*. (2002), Suárez *et al*. (2003) and Ribas *et al*. (2004), in other tropical breeds such as Carora (5/8 Brown Swiss 3/8 Creole) and Siboney de Cuba.

The repeatability estimate was also inferior in the P2. The value of the whole data corresponded with the reports of Vargas and Solano Patiño (1995), Gómez and Tewolde (1999), Bhuiyan *et al*. (2000), De Almeida *et al*. (2000), Pérez and Gómez (2005) and Facó *et al*. (2009) for Holstein, Brown Swiss and Girolando.

The correlations between the genetic values, estimated for milk production up to 305 d, in the sires assessed in different production levels are shown in table 2. The value of the sintetic corelations between the production levels P1 and P2 (0.66) was inferior to 0.8. According to Robertson (1959), inferior correlation values as this, suggests that the interaction genotype-environment is biologically important.

When analyzing the whole data (P3), a higher genetic correlation was obtained with the production level P1 (0.97). Therefore, the best animals assessed in all years were, mostly, those of the first period.

Mulder (2007) concluded that when the genetic correlation is higher than 0.60, it is more appropriate to carry out a unique genetic program with progeny tests for the bulls in both environments. On the contrary, when the genetic correlation was lower or equal to 0.60,

Table 2. Pearson's correlations between the genetic values estimated for milk production up to 305 d in Mambi de Cuba sires, assessed in different production levels

	P2	P3
P1	0.66	0.97
P2		0.74

*** P< .0001

a specific genetic program was more opportune, as well as progeny tests in each environment.

The progenies of the sires analyzed did not have the same performance in the different environments. There were alterations in the classification order (merit) of the genotypes, as evidence of the interaction genotype-environment. Figure 5 shows the estimates of the genetic values of 20 sires assessed in both environments for milk production, up to 305 d.

Different authors have referred the existence of interaction genotype-environment in the dairy production, when considering the interaction between different management and feeding (or between different regions), whether in a same country or between different countries.

In the Holstein breed, Cerón-Muñoz *et al*. (2001) studied the dairy production up to 305 d in four regions of Colombia. They informed interaction genotype-environment between Cundinamarca and the other three regions, with coefficients of genetic correlation from 0.70 to 0.83. Nauta *et al*. (2006) also observed IGE when comparing the organic and traditional production systems in Holland (genetic correlation of 0.80). Valencia *et al*. (2008), in three Mexican regions, obtained values of 0.73, 0.38 and 0.93 for the correlations between North-Center, North-South and Center-South, respectively. Carneiro *et al*. (2009) referred genetic correlations from 0.09 to 0.57, when analyzing the dairy production in seven dairy regions of Paraná state, Brazil.

In Cuba, Suárez *et al*. (2009) obtained an estimate of 0.49 for the genetic correlation between the genetic values of the milk production at 244 d in Siboney from Cuba, in different environments.

When analyzing the existence of IGE for milk production in Holstein in different countries, genetic correlations from 0.60 to 0.71 were obtained between different environments of Mexico and United States (Cienfuegos-Rivas *et al*. 1999). Chagunda *et al*. (1999) obtained 0.44 for the genetic correlation between Malawi

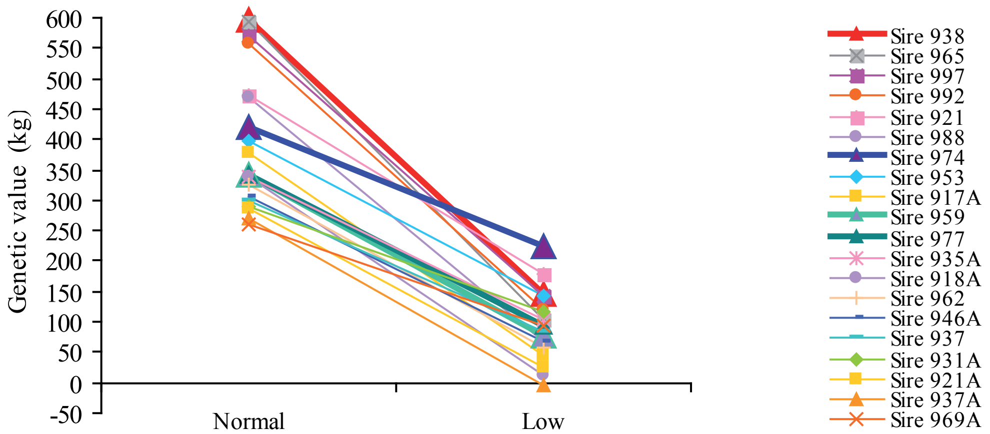

Figure 5. Genetic values estimated for milk production up to 305 d, of 20 sires assessed in two production levels: normal and low

and Canadá. Ojango and Pollot (2002) informed value of 0.49 between Kenya and the United Kingdom. Cerón-Muñoz *et al*. (2004) referred 0.74 between Brazil and Colombia. The estimate between Luxemburg and Tunisia was of 0.60 (Hammami *et al*. 2008).

The genetic correlations between the predicted transmitter abilities for milk production of the sires (PTA) of IA used in Costa Rica and USA were of 0.62 in Holstein and 0.78 in Jersey (Vargas and Gamboa 2008). Montaldo *et al*. (2009) found genetic correlations between the PTA for milk production: 0.74 between Mexico and United States, 0.77 between Mexico and Canada and 0.92 between Canada and United States.

In general, the genetic correlations for milk production were low. Thus, there was IGE between countries and regions differing considerably in the weather, management and production system.

In other studies, no IGE was appreciated in milk production traits. Among them, Carabaño *et al*. (1990) studied the performance of Dutch cows, daughters of a same sire in different regions of the United States (California, New York and Wisconsin). They estimated genetic correlations of 0.99 between New York and Wisconsin, 0.95 between California and New York, and 0.94 between California and Wisconsin.

Boettcher *et al*. (2003), when comparing herds of Holstein cows in Canada in intensive rotational grazing system, obtained genetic correlation of 0.96 ± 0.04 for milk production up to 305 d, in respect to conventional methods. In this study, only scale effect was found. Fikse *et al*. (2003), in Guernsey cows assessed in four countries (Australia, Canada, United States and South Africa) obtained genetic correlations between 0.78 and 0.90.

Mulder *et al*. (2004), when assessing the milk production on the control day between farms with automatic milking and farms with conventional systems, found genetic correlation of 0.93. They established the same period and values of 0.89, when considering the correlations within farms between the previous and posterior to the introduction of the automatic milking.

Bueno *et al*. (2005) verified the effect of the interaction sire per herd and sire per herd and year in the genetic values of Brown Swiss sires. The highest values (> 0.99) for the correlations of Pearson and Spearman between the genetic values predicted of the sires for milk and fat production indicated that the order of the sires was not altered with the inclusion of the interaction effects on the models.

Haile-Mariam *et al*. (2008), in Australian Holstein-Friesian cows, did not find either IGE through the estimation of genetic correlations for the characteristics of milk production between different calving systems (seasonal and during the whole year), with values over 0.96. Similar results were proved between different regions of Australia, with genetic correlations between 0.94 and 0.99.

In this study, the estimate of 0.66 for the genetic correlation between the genetic values of milk production, in the 93 sires assessed in both production levels, showed IGE in Mambi de Cuba. The daughters of the best sires in P1 had their genetic expression for the limited milk production in P2. It is concluded that for using Mambi de Cuba sires, the environmental conditions should be considered for optimizing the genetic improvement and increase productivity.

References

Alencar, M.M., Mascioli, A.S. & Freitas, A.R. 2005. Evidências de interação genótipo x ambiente sobre características de crescimento em bovinos de corte. Ver. Bras. Zootec. 34:489

Anon 2009. El clima en Cuba. In: http://www.bedincuba.com/2climaencuba.htm.Consulted: 10/09/12

Bhuiyan, S. A., Ali, A., Bhuiyan, A.K.F.H. & Bhuiyan, M.M. 2000. Genetic and phenotypic parameters on some economic traits in dairy cows. Bangladesh J. Anim. Sci. 29:143

Boettcher, P., Fatehi, J.J. & Schutz, M. M. 2003. Genotype x environment interactions in conventional versus pasture-based dairies in Canada. J. Dairy Sci. 86: 383

Bueno, R. S., de Almeida Torres, R., Palma Rennó, F., Pereira, J. C., Vieira de Araújo, C., Lopes, P. S. & Euclydes, R. F. 2005. Efeito da interação reprodutor x rebanho sobre os valores genéticos de reprodutores para produção de leite e gordura na raça Pardo-Suíça. Rev. Bras. Zootec. 34:1156

Carabaño, M. J., Wade, K. M. & van Vleck, L.D. 1990. Genotype by environment interactions for dairyand fat production across regions of the United States. J. Dairy Sci. 73:173

Carneiro de Paula, M., Elias Nunes, M., Campos da Silva, L. O., Lopes de Oliveira, C. A., Altair Antônio Valotto, A. A. & Pohl Ribas, N. 2009. Interação genótipo × ambiente para produção de leite de bovinos da raça Holandesa entre bacias leiteiras no estado do Paraná. Rev. Bras. Zootec. 38:467

Cerón-Muñoz, M. F., Tonhati, H., Costa, C. & Benavides, F. 2001. Interacción genotipo-ambiente en ganado Holstein colombiano. Arch. Latinoam. Prod. Anim. 9:74

Cerón-Muñoz, M.F., Tonhati, H., Costa, C.N., Rojas Sarmiento, D. & Solarte Portilla, C. 2004. Interação genótipo - ambiente em bovinos da raça Holandesa Brasileiros e E Colombianos. Arch. Zootec. 53: 239

Chagunda, M.G., Bruns, E.W., King, J.M. & Wollny, C.B.A. 1999. Genotype by environment interaction for dairyyield of Canadian Holstein Friesian on large scale dairy farms in Malawi. Deutscher Tropentag 1999 in Berlin. Session: Sustainable Technology Development in Animal Agriculture

Cienfuegos-Rivas, E.G., Oltenacu, P.A., Blake, R.W., Schwager, S.J., Castillo-Juarez, H. & Ruiz, F. J. 1999. Interaction between dairy yield of Holstein cows in Mexico and the United States. J. Dairy Sci. 82:2218

De Almeida, R., Vieira, C., Napolis, C., Garcia, J. A., De Almeida, R. & Silva, C. 2000. Ajustamento da produçao de leite para os efeitos simultâneos de ordem, idade e estaçao de parto. Rev. Brasil. de Zoot. 8: 2253

Facó, O., Martins, R., Nonato, R., Lobo, B., Machado, D. M. & Pinheiro, S. M. 2009. Efeito da redução da variação da duração de lactação na avaliação genética de bovinos leiteiros mestiços. Rev. Ciência Agronômica 40:287

Fikse, W.F., Rekaya, R. & Weigel, K.A. 2003. Genotype by environment interaction for dairyproduction traits in Guernsey cattle. J. Dairy Sci. 86:1821

Gilmour, A.R., Gogel, B.J., Cullis, B.R., Welham, S.J. & Thompson, R. 2003. ASREML. User Guide Release 1.10.

Gómez, H. & Tewolde, A. 1999. Parámetros genéticos para producción de leche, evaluación de sementales y caracterización de fincas lecheras en el trópico húmedo de Costa Rica. Archiv. Latinoam. Prod. Anim. 7:19

Guerra, D., Evora, J.C., de Bien, R. & Prada, N. 2002. Evaluación genética de la raza Siboney de Cuba. II Congreso Internacional de Mejoramiento Animal. XVIII Congreso Panamericano de Ciencias Veterinarias. Palacio de las Convenciones. La Habana, Cuba Haile-Mariam, M., Carrick, M. J. & Goddard, M.E. 2008. Genotype by environment interaction for fertility, survival, and dairyproduction traits in Australian Dairy Cattle. J. Dairy Sci. 91:4840

Hammami, H., Rekik, B., Soyeurt, H., Bastin, C., Stoll, J. & Gengler, N. 2008. Genotype x environment interaction for dairyyield in Holsteins using Luxembourg and Tunisian populations. J. Dairy Sci. 91: 3661

Montaldo, H. H., Núñez-Soto, S.G., Ruiz-López, F.J. & Castillo-Juárez, H. 2009. Selection response for dairyproduction in conventional production systems in Mexico, using genetic evaluations of Holstein sires from Canada and the United States J. Dairy Sci. 92:5270

Mulder, H.A. 2007. Methods to optimize livestock breeding programs with genotype by environment interaction and genetic heterogeneity of environmental variance. PhD Thesis: Wageningen University. The Netherlands

Mulder, H. A., Groen, A. F., De Jong, G. & Bijma, P. 2004. Genotype x environment interaction for yield and somatic cell score with automatic and conventional milking systems. J. Dairy Sci. 87:1487

Nauta, W. J., Veerkamp, R. F., Brascamp, E.W. & Bovenhuis, H. 2006. Genotype by environment interaction for dairy production traits between organic and conventional dairy cattle production in The Netherlands. J. Dairy Sci. 89: 2729

Ojango, J.M. K. & Pollot, G. E. 2002. The relationship between Holstein bull breeding values for dairy yield derived in both the UK and Kenya. Livest. Prod. Sci. 74:1

Pérez, G. A. & Gómez, M. G. 2005. Factores genéticos y ambientales que afectan el comportamiento productivo de un rebaño Pardo Suizo en el trópico. 1. Producción de leche. Rev. Cient. 15:141

Ribas, M., Gutiérrez, M., Mora, M., Evora, J.C. & González, S. 2004. Productive and reproductive performance of Siboney de Cuba in two regions. Cuban J. Agric. Sci. 38:119

Robertson, A. 1959. The sampling variance of the genetic correlation coefficient. Biometrics 15:469

SAS. 2002. User's Guide Statistics. SAS Institute Inc. Cary, NC.USA.

Suárez, M. A., Zubizarreta, I. & Pérez, T. 2009. Interacción genotipo ambiente en ganado bovino Siboney de Cuba. Livestock Res. Rural Develop. 21 (9)

Suárez, M.A., Fernández, L., Pérez, T., Quincosa, J., Álvarez, A., Pérez, E., Evora, J.C., Menéndez Buxadera, A., González, M.T. & Marrero, A. 2003. Siboney de Cuba: Nuevo genotipo para la producción de leche y carne. Informe Técnico. 198 pp.

Valencia, M., Montaldo, H.H. & Ruíz, F. 2008. Interaction between genotype and geographic region for dairy production in Mexican Holstein cattle. Arch. Zootec. 57: 457

Valle, A. & Moura, F.A. 1986. Herencia de los principales parámetros productivos y reproductivos en vacas mestizas (5/8 Pardo Suizo - 3/8 criollo) tipo Carora. Rev. Zootec. Trop. 4:49

Vargas L.B. & Solano Patiño, C. 1995. Tendencias genéticas y ambientales en producción de leche en vacas lecheras de Costa Rica. Arch. Latinoam. Prod. Anim. 3:165

Vargas, B. & Gamboa, G. 2008. Estimación de tendencias genéticas e interacción genotipo x ambiente en ganado lechero de Costa Rica. Téc. Pec. Méx. 46: 371

Weigel, K.A., Gianola, D., Yandell, B.S. & Keown, J. F. 1993. Identification of factors causing heterogeneous withing-herd variance components using a structural model for variances. J. Dairy Sci. 76: 1466

Received: January 9, 2012